Fermilab

TM-1236
2125.000

COLLIDER DETECTOR BEAM LINE TEST TABLE

A STRUCTURAL ANALYSIS

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Abstract

The apparatus which sweeps calorimeter and endwall modules through the beam during testing is called a beam line test table. Because of rather stringent requirements for the physical positioning of the modules an analysis is done here to determine the modifications to the current test table design which will minimize deflections of the table under load.

Introduction

Fig. 1a-c shows the test table assembly. Calorimeter modules and endwall modules are stacked on this table which can then be rotated about a pivot point on the floor or raised at an angle using a hydraulic jack. The ultimate goal is to be able to support the modules in such a way that they remain parallel to the floor (no "tipping" of the table) and that the total deflection of the table under load be as small as possible. Because of space considerations, there are only so many ways one can reinforce this table to achieve the desired results. This analysis specifically addresses three questions:

1. How much will reinforcing the inner frame help in reducing deflections due to the load of a module.
2. How does the outer frame of the test table respond to the loading of the inner table.
3. How does the outer frame respond to horizontal loads.

Analysis

Figs. 2-5 show the model used for the inner frame of the test table, Figs. 6-8 show the outer frame. For those familiar with finite element analysis, the inner frame required modeling using plate elements because the effects of adding stiffening plates to the top and bottom of the frame needed to be examined, whereas the outer frame would not allow the addition of stiffening plates so that 3-D beam elements were sufficient. While the physical size of the two problems is similar, the plate elements required 20 times more solution time than the beam elements.

Fig. 9 shows the distorted geometry plot of the inner frame due to loading by one calorimeter module (30,000 lb). The maximum deflection at the corner of the frame is 2.66 in. Note that this deflection results from a fairly severe warping of the frame.

Fig. 10 shows the distorted geometry plot of the outer frame due to the reaction forces of the inner frame. Fig. 11 shows the magnitude and direction of these reaction forces. The deflection of interest is at the point where the hydraulic jack connects the outer frame to the inner frame, for this deflection determines the outer frame's contribution to the modules net motion. This deflection turns out to be 0.051 in. The net deflection of the corner of the inner frame (the point of maximum deflection) then becomes 2.66 + 0.05 = 2.71 in.

An actual loading of the test table with a dummy module resulted in an observed deflection of 2-3/4. Because the table is fairly high off the ground and in a confined space, this deflection was measured with a yardstick relative to the floor. It is reasonable to say that given the accuracy of the measurement, the model gives a fairly accurate representation of what the real structure is doing.

The first modification to be examined is the addition of 1/2 in. steel plates in the areas shown in Figs. 12 and 13. These plates are added on top and bottom. Fig. 9 shows the resulting distorted geometry plots. The maximum deflection is now 0.25 in. as compared with 2.66 in. without the plates. Clearly the effort involved in adding these plates is worth it. The net deflection of the corner of the inner frame now is reduced to 0.05 + 0.30 = .035 from the previous 2.71 in.

One further point needs to be made. The previous analysis assumed that half of the module weight was supported at each of the two points labeled 1 and 2 indicated in Fig. 14. It can be argued that this is a best case analysis because the fact is that the four corners of the module do not remain in contact with the table. At the point labeled 4 in Fig. 14, the module actually lifts off the table about 1/2 in. For this reason, a worst case analysis might be taken as one-third of the module weight being applied to each of points 1, 2, and 3 rather than half the load applied to each of points 1 and 2. When this worst case is assumed, the deflection of the inner table increases from 0.25 in. to 0.45 in. The maximum stresses increase from 6,300 psi to 10,800 psi. However, assuming the worst case analysis also leads to the conclusions that the addition of plates top and bottom on the test table offers tremendous improvement in performance.

Returning to the subject of the outer frame, its deflection (given earlier) is not excessive, nor are stress levels. Stress levels along the beam which carries the two rollers peak at almost 7,900 psi.

Because it is proposed that the table be used to test two modules at a time, the previous deflections and stress levels should be doubled. Stress levels then become 15,800 psi in the outer frame. A modification is proposed to reduce this stress level.

The proposed modification to solve this stress problem is the addition of another Hillman roller directly under the point labeled 1 in Fig. 15 which corresponds to the location directly under the hydraulic jack. Figs. 16 and 17 show the displacements for this load case, the maximum displacement being 0.092 in. at a point approximately midway between the hinge supports for the inner table. The maximum stresses in this case are approximately

7,000 psi near the same location as the maximum displacement. The values are for a one module load.

Finally, the question of horizontal forces acting on the lower frame must be addressed. Referring to Fig. 18, a horizontal force of 2,000 lbs. is applied at each of points 1 and 2 directed as shown. These horizontal forces are resisted by points 3 and 4: The pivot point on the floor and the point of application of the load from the hydraulic jack which rotates the whole structure about the pivot point. Fig. 19 shows the resulting "rotational displacement" of 0.483 in. The maximum stress is 17,000 psi in the element labeled point 5 in Fig. 18.

Summary

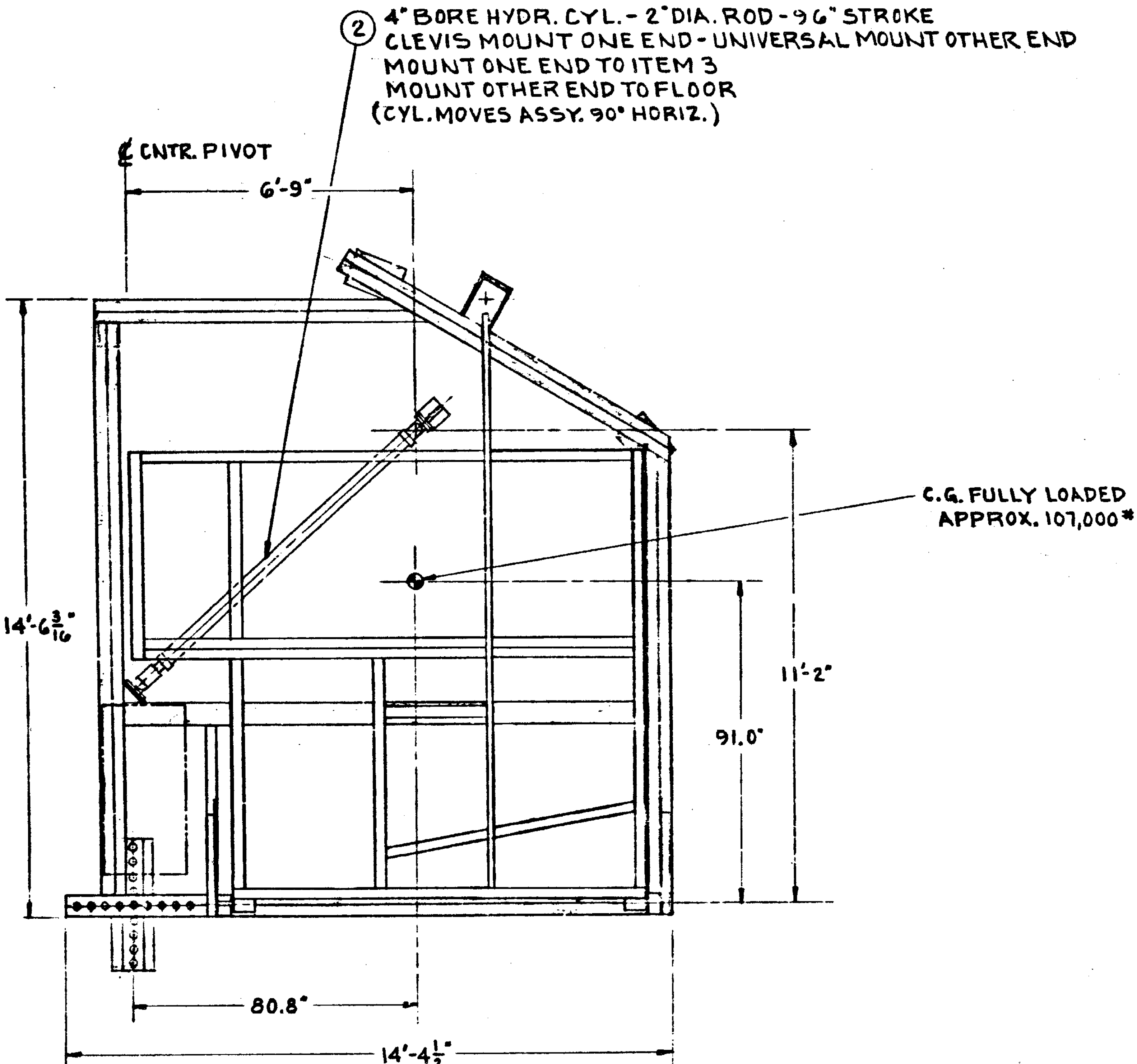
Assuming the following modifications are made:

1. One-half in. steel plates welded on top and bottom of inner frame as described earlier, and
2. Hillman roller added under the hydraulic jack on the outer frame,

the following table summarizes displacements and stresses for single module loading (30,000 lbs.).

	Inner Frame	Outer Frame
Maximum displacement	0.25 in.	0.092 in.
Location	Point 3 in Fig. 14	Point 1 in Fig. 21
Maximum stress	6,300 psi	7,000 psi
Location	Marked MX in Fig. 20	Point 2 in Fig. 21

The above values should be doubled to account for loading of two modules.



PLAN VIEW

Fig. 1a

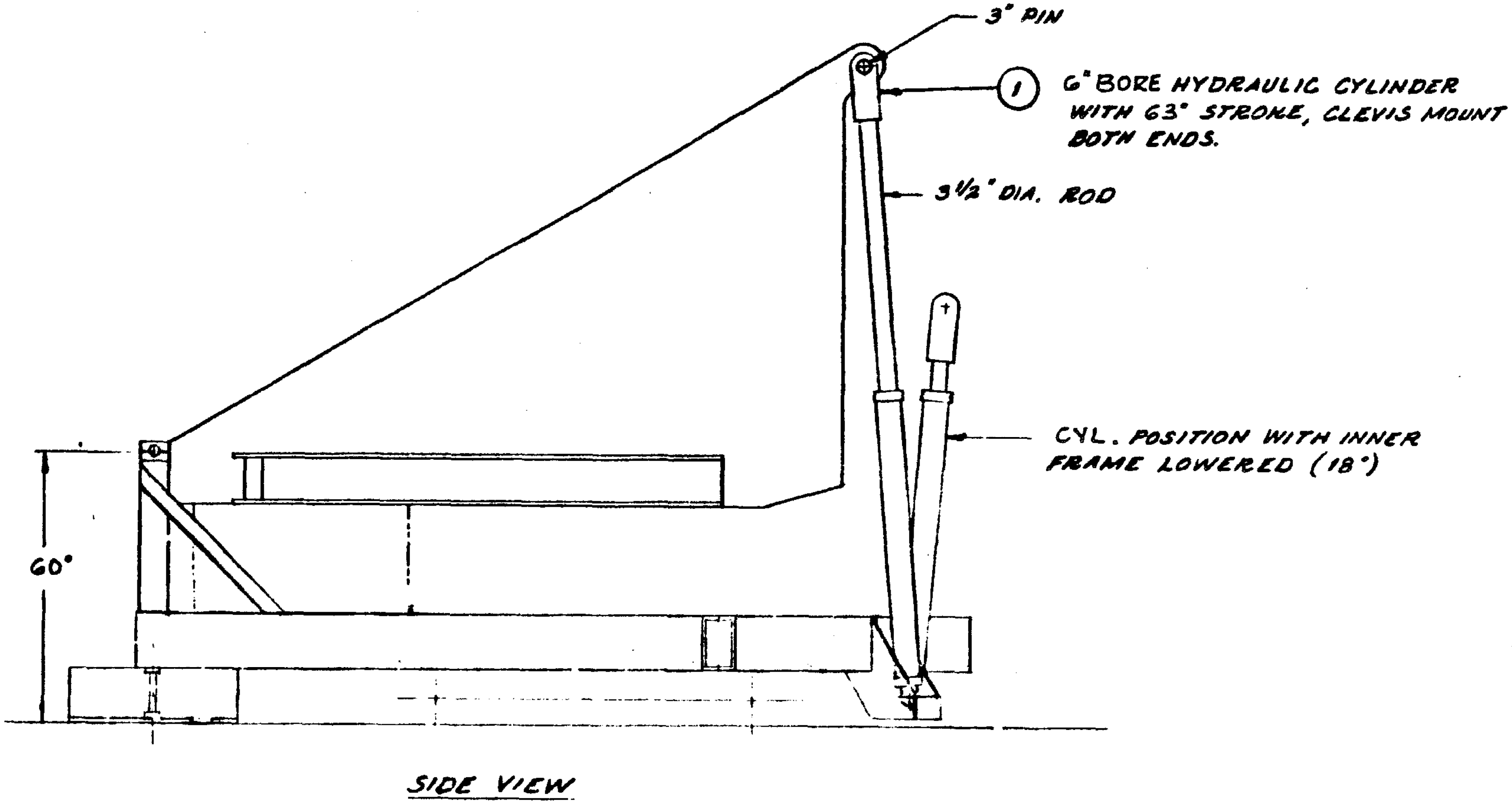
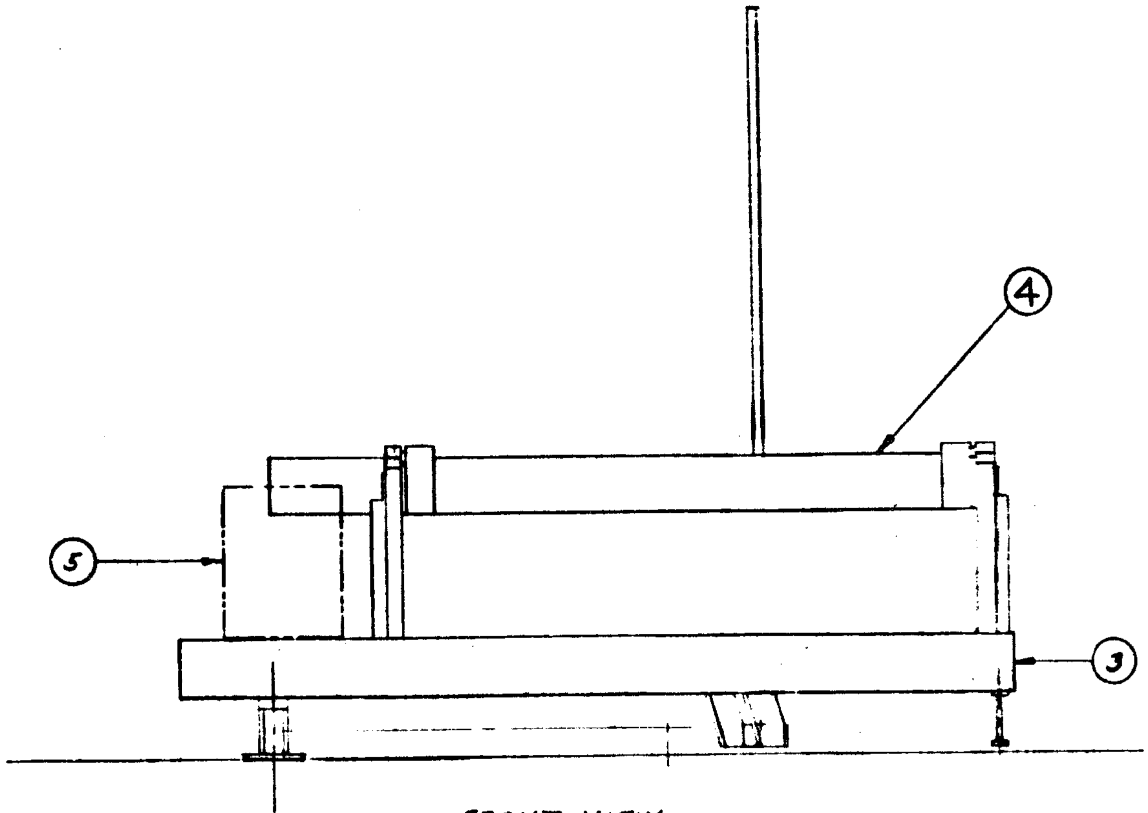
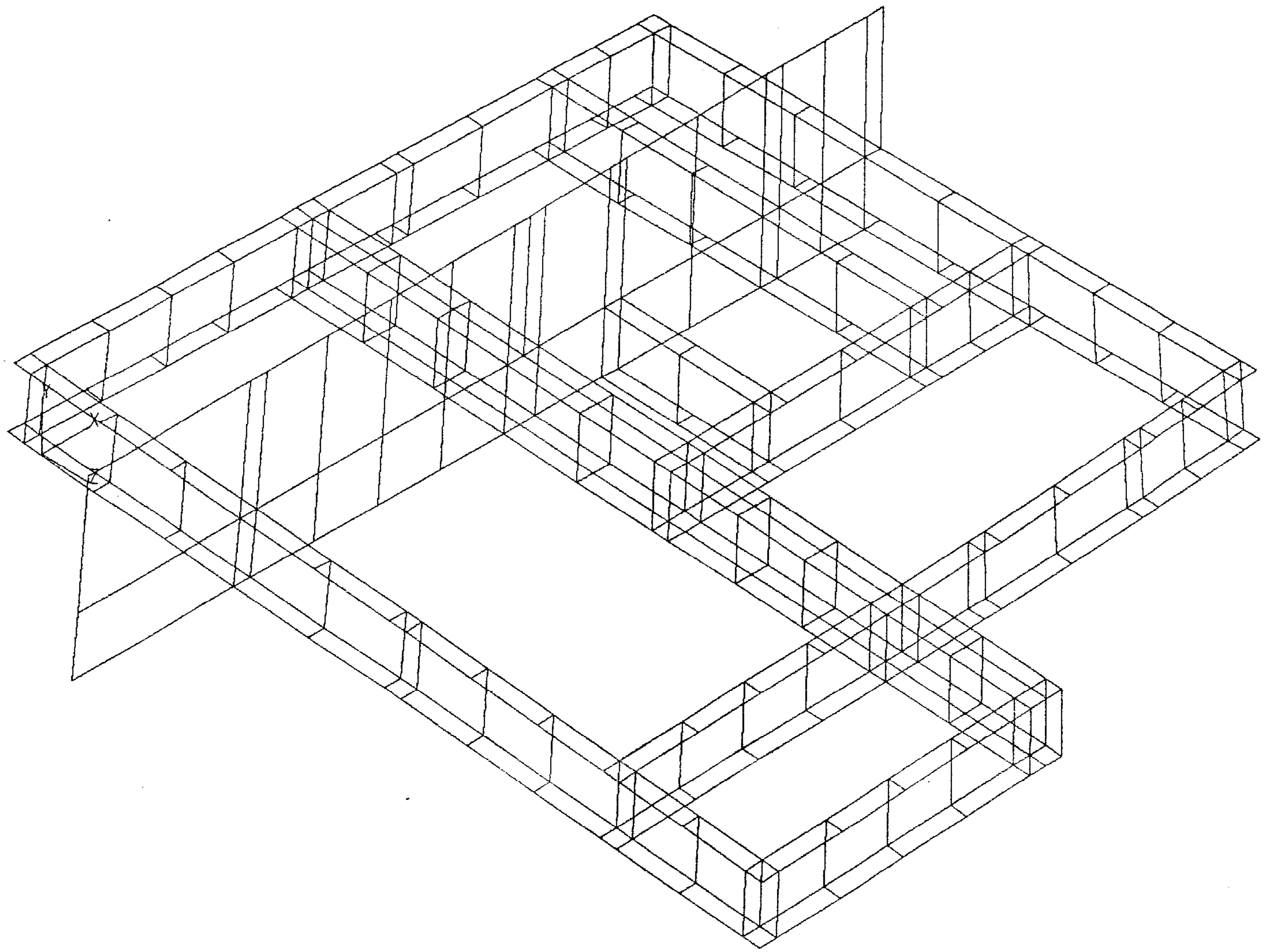

3" PIN
1
6" BORE HYDRAULIC CYLINDER WITH 63" STROKE, CLEVIS MOUNT BOTH ENDS.
3 1/2" DIA. ROD
CYL. POSITION WITH INNER FRAME LOWERED (18°)
60"
SIDE VIEW

Fig. 1b



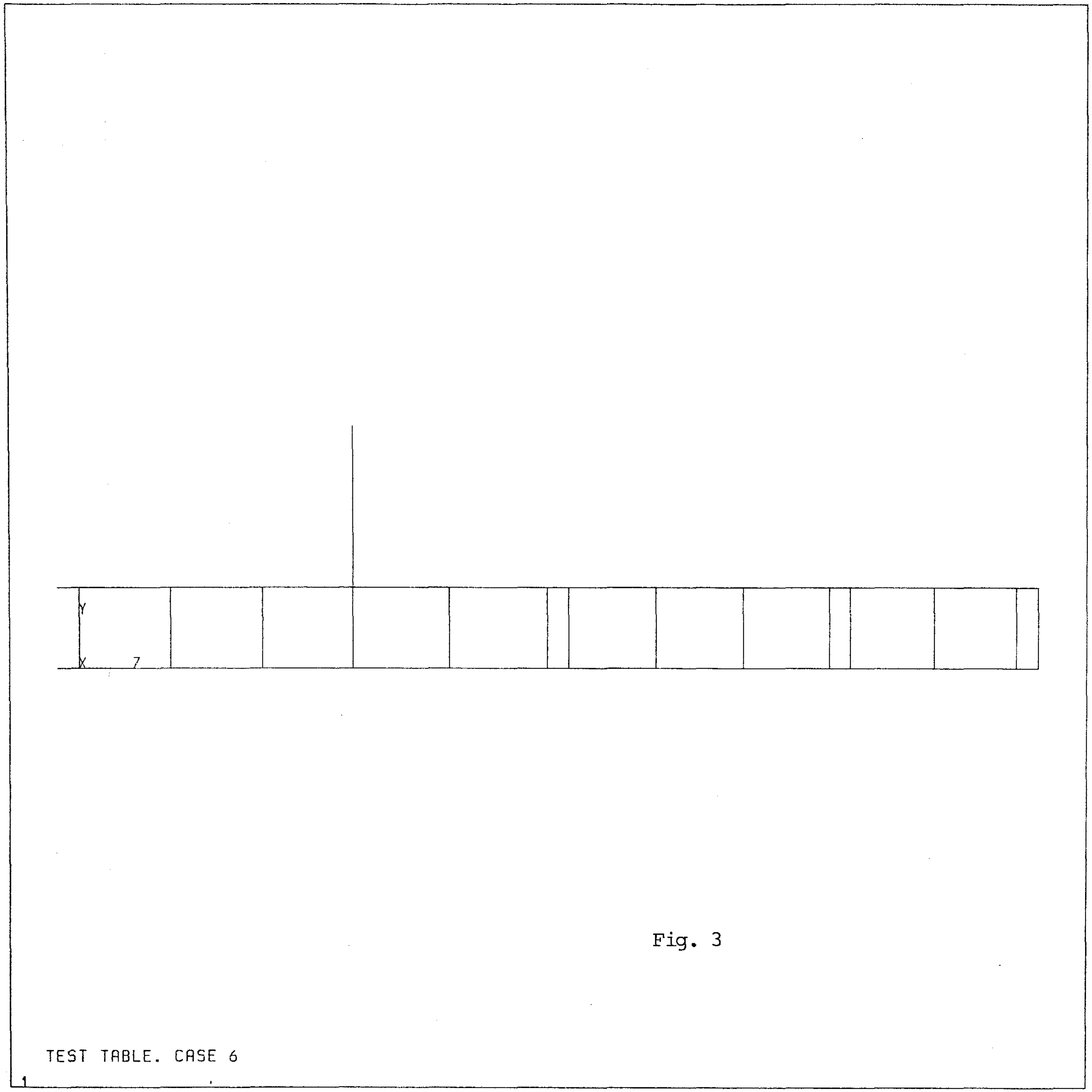
FRONT VIEW

Fig. 1c


ANSYS
83/12/ 9
15.1447
PLOT NO. 3
POST1
STEP=1
ITER=1
DISPLACEMENT

ORIG SCALING
XV=-1
YV=1
ZV=1
DIST=94.8
XF=52.8
YF=6.64
ZF=62.7
DMAX=2.67
DSCA=3.54
TEST TABLE. CASE 3.

Fig. 2



ANSYS
83/12/ 9
14.4442
PLOT NO. 3
POST1
ELEMENTS
ORIG SCALING
XV=-1
DIST=80.5
XF=43.6
YF=18
ZF=70
Y
X
Z
TEST TABLE. CASE 6
1

Fig. 3

ANSYS
83/12/ 9
14.4494
PLOT NO. 4
POST1
ELEMENTS

ORIG SCALING
ZV=1
DIST=86.4
XF=43.6
YF=18
ZF=70

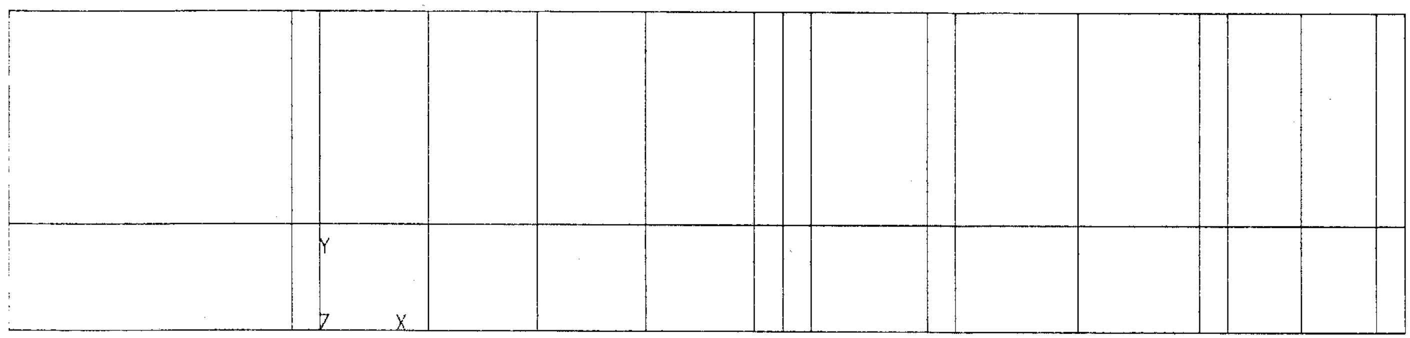
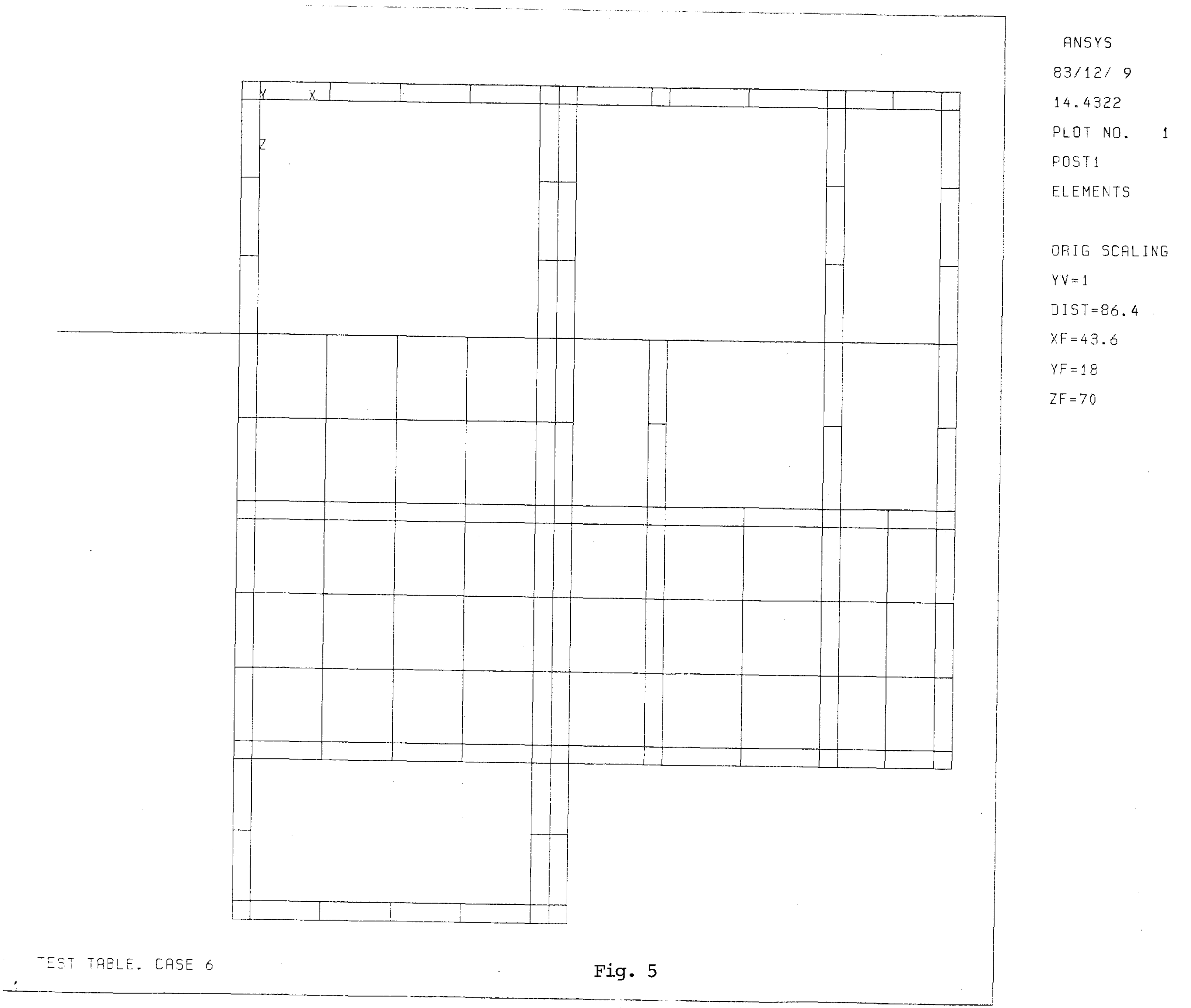


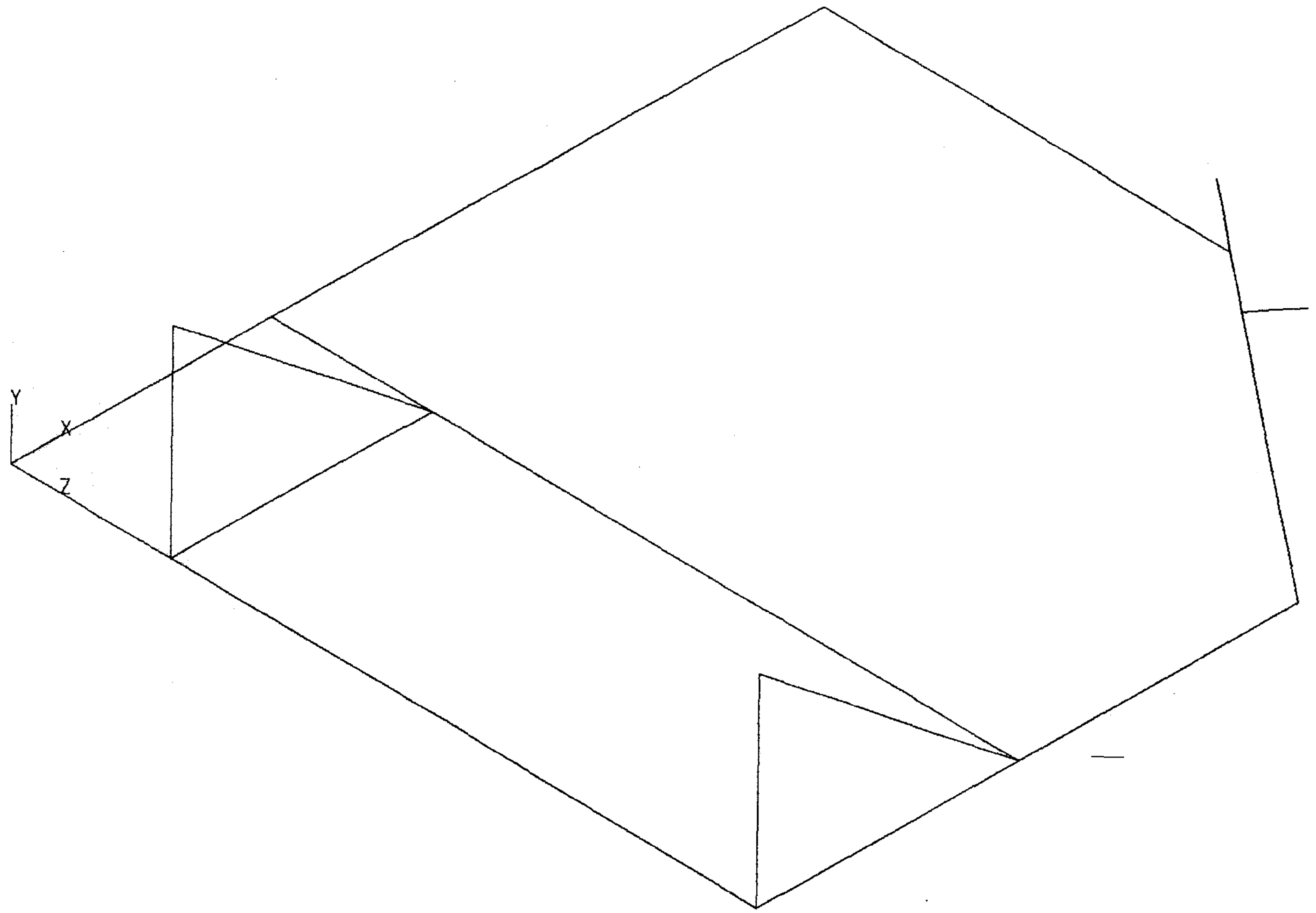
Fig. 4

TEST TABLE. CASE 6



Y
X
Z
ANSYS
83/12/ 9
14.4322
PLOT NO. 1
POST1
ELEMENTS
ORIG SCALING
YV=1
DIST=86.4
XF=43.6
YF=18
ZF=70
TEST TABLE. CASE 6

Fig. 5



ANSYS
84/ 1/ 4
10.4692
PLOT NO. 5
POST1
ELEMENTS

ORIG SCALING
XV=-1
YV=1
ZV=1
DIST=105
XF=63.4
YF=7
ZF=71.6

Fig. 6

OUTER FRAME. CASE 1.

ANSYS
84/ 1/ 4
10.4644
PLOT NO.
POST1
ELEMENTS

ORIG SCALING
ZV=1
DIST=98.7
XF=89.7
YF=21
ZF=78.1

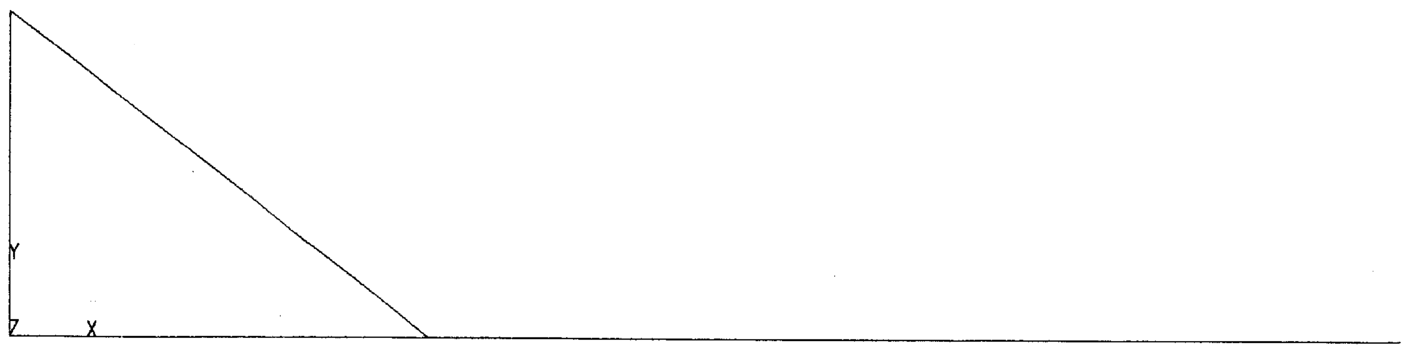


Fig. 7

OUTER FRAME. CASE 1.

ANSYS
84/ 1/ 4
10.4603
PLOT NO.   3
POST1
ELEMENTS

ORIG SCALING
XV=-1
DIST=85.9
XF=89.7
YF=21
ZF=78.1

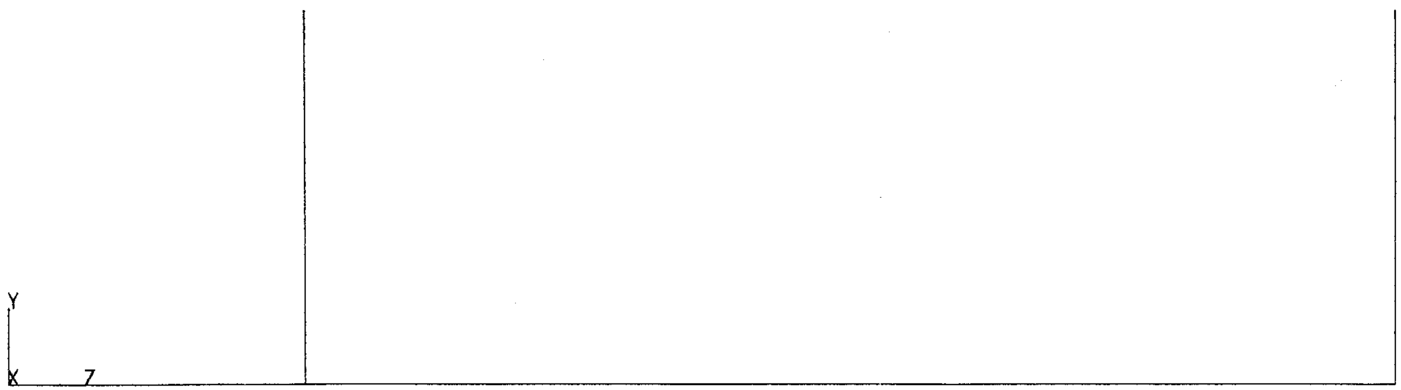
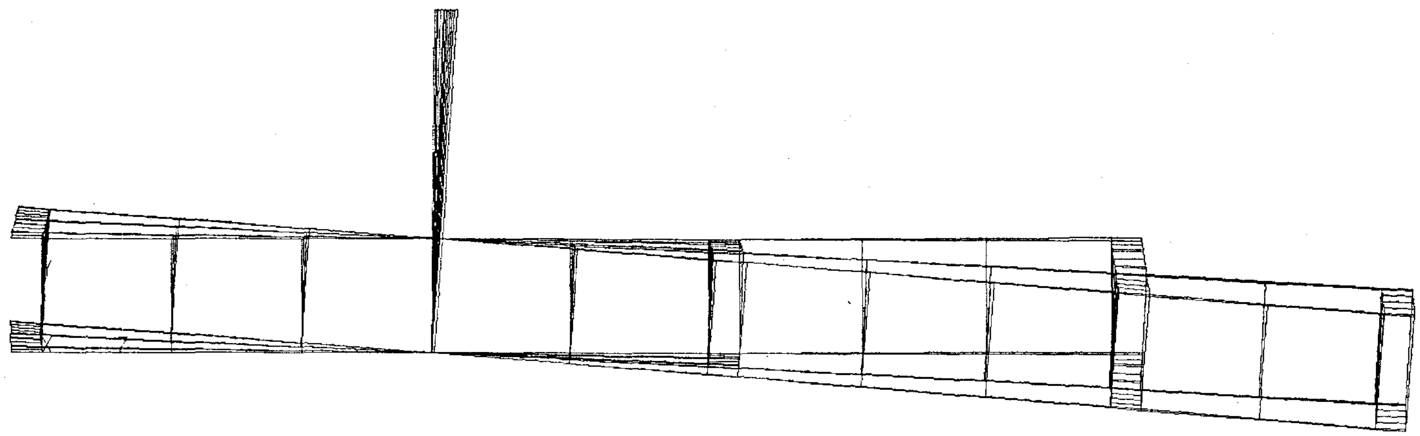


Fig. 8

OUTER FRAME. CASE 1.

1



ANSYS
83/12/ 9
15.1347
PLOT NO. 2
POST1
STEP=1
ITER=1
DISPLACEMENT

ORIG SCALING
XV=-1
DIST=80.5
XF=43.6
YF=18
ZF=70
DMAX=2.67
DSCA=3.01

Fig. 9

TEST TABLE. CASE 3.

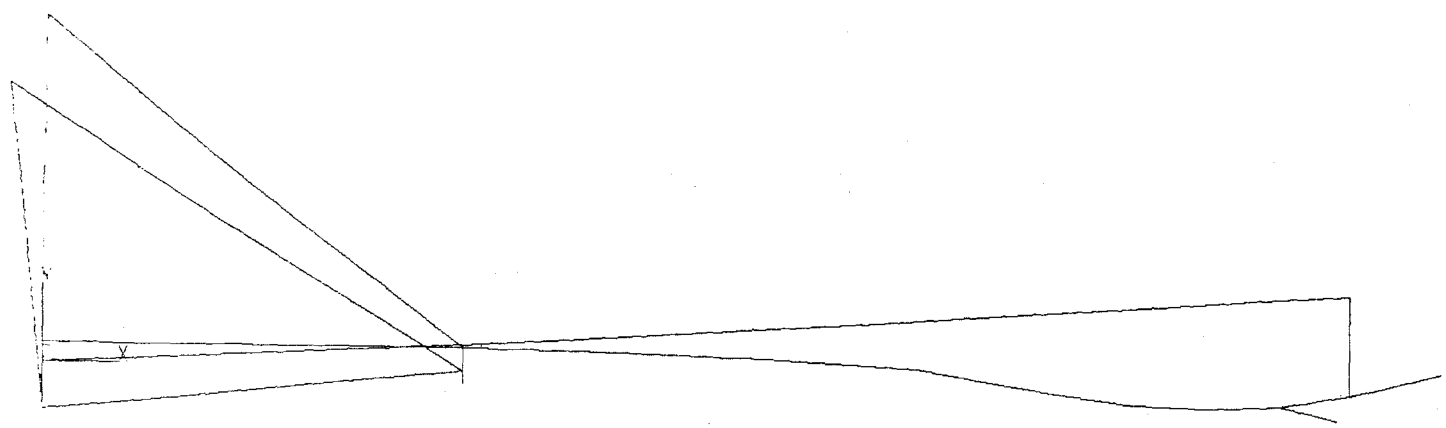
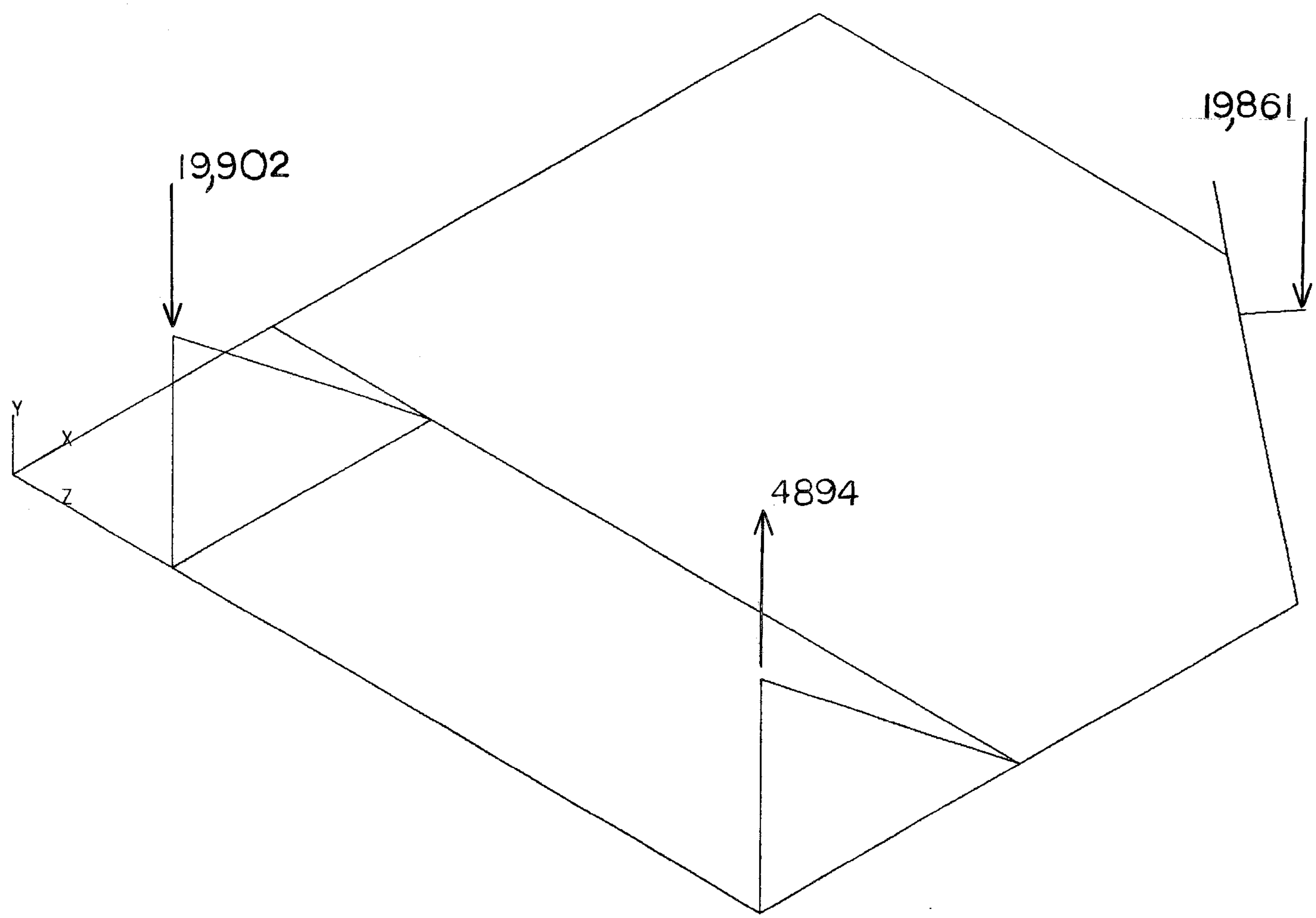

ANSYS
84/ 1/ 3
14.5792
PLOT NO.
POST1
STEP=1
ITER=1
DISPLACEMENT
ORIG SCALING
ZV=1
DIST=98.7
XF=89.7
YF=21
ZF=78.1
DMAX=.0834
DSCA=118
OUTER FRAME. CASE 1.

Fig. 10



ANSYS
84/ 1/ 4
10.4692
PLOT NO.
POST1
ELEMENTS

ORIG SCALING
XV=-1
YV=1
ZV=1
DIST=105
XF=63.4
YF=7
ZF=71.6

Fig. 11

OUTER FRAME. CASE 1.

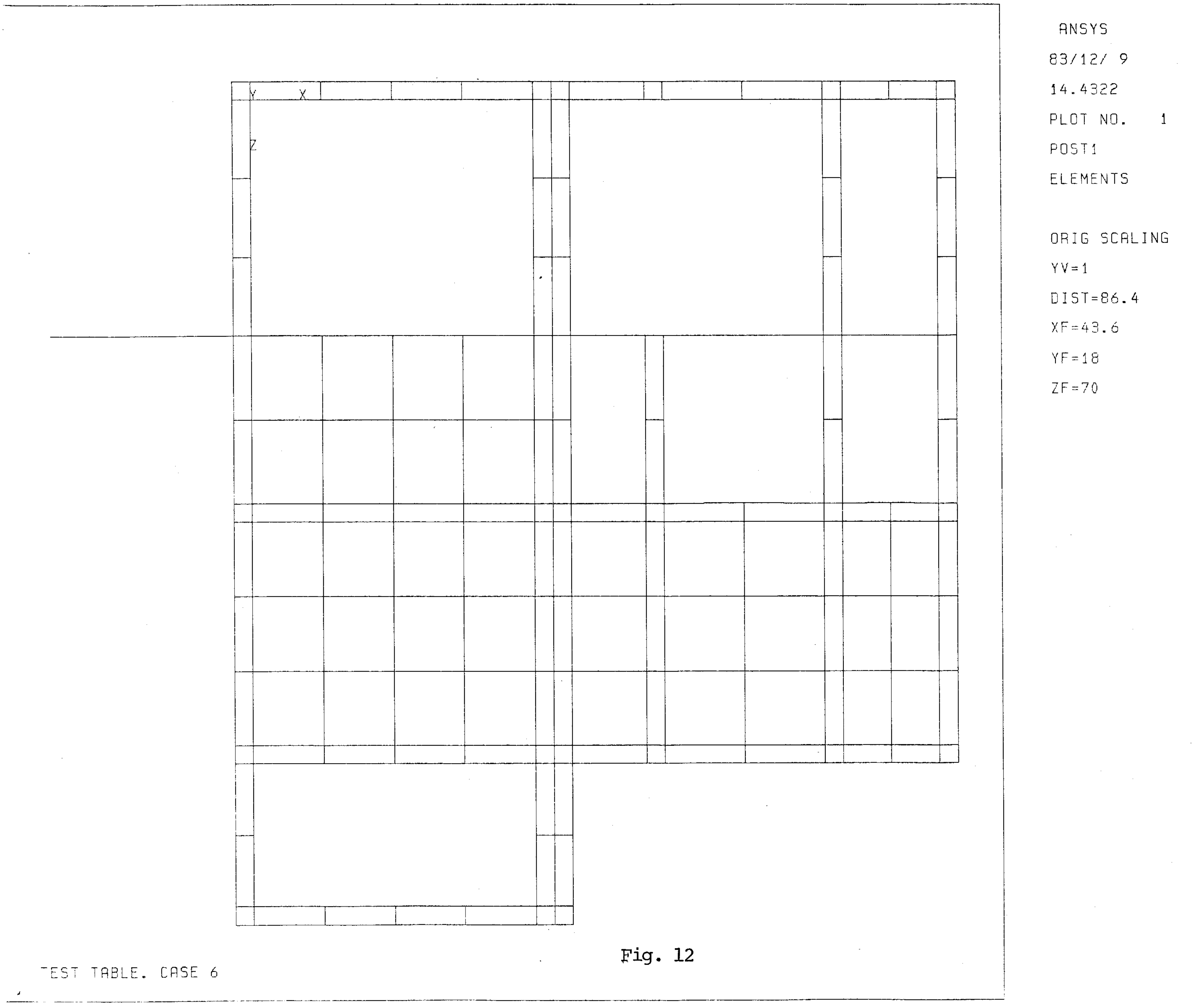
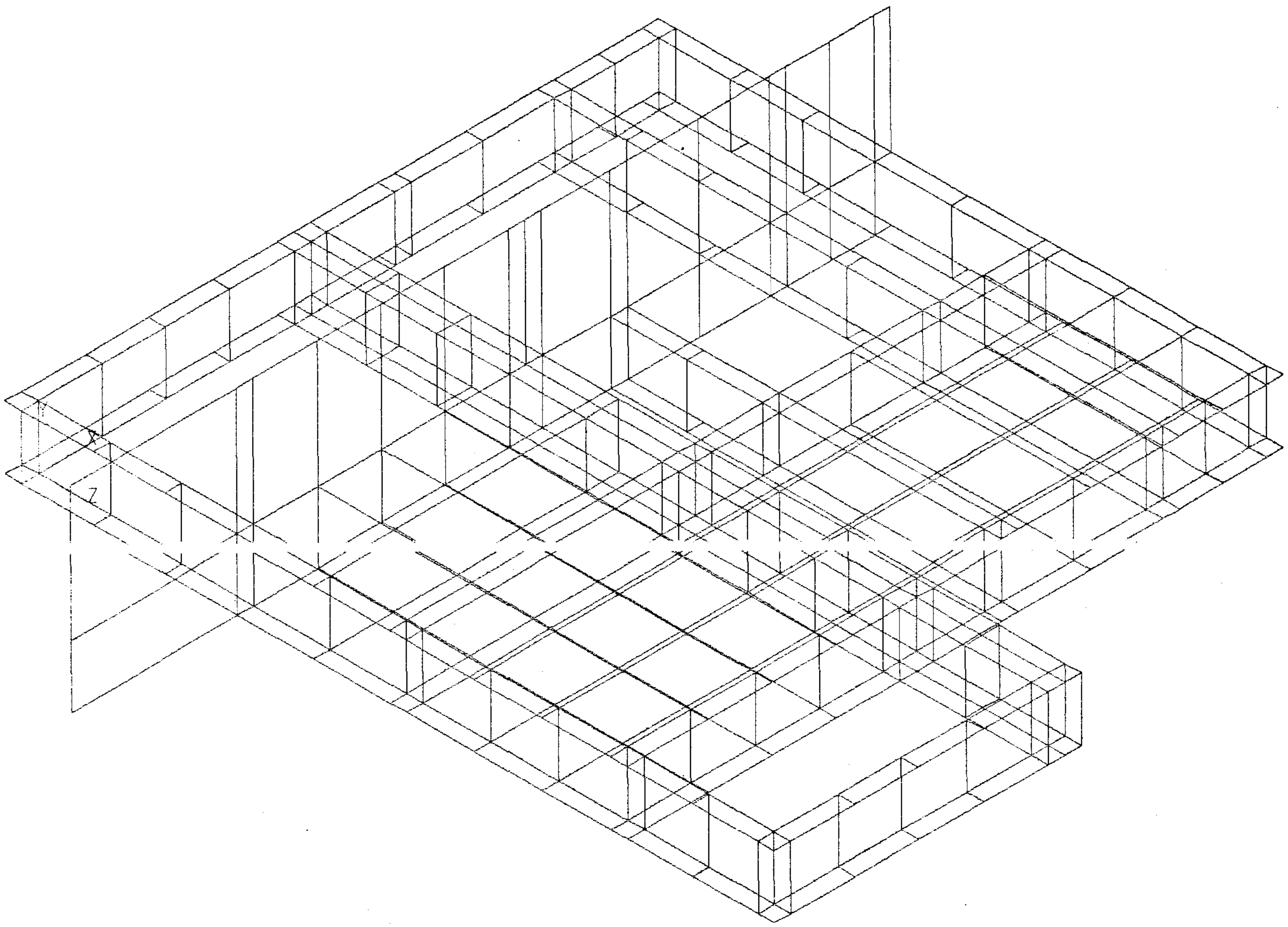

ANSYS
83/12/ 9
14.4322
PLOT NO. 1
POST1
ELEMENTS
ORIG SCALING
YV=1
DIST=86.4
XF=43.6
YF=18
ZF=70
Y
X
Z
TEST TABLE. CASE 6

Fig. 12



ANSYS
83/12/ 9
14.4378
PLOT NO. 2
POST1
ELEMENTS

ORIG SCALING
XV=-1
YV=1
ZV=1
DIST=94.8
XF=52.8
YF=6.64
ZF=62.7

Fig. 13

TEST TABLE. CASE 6

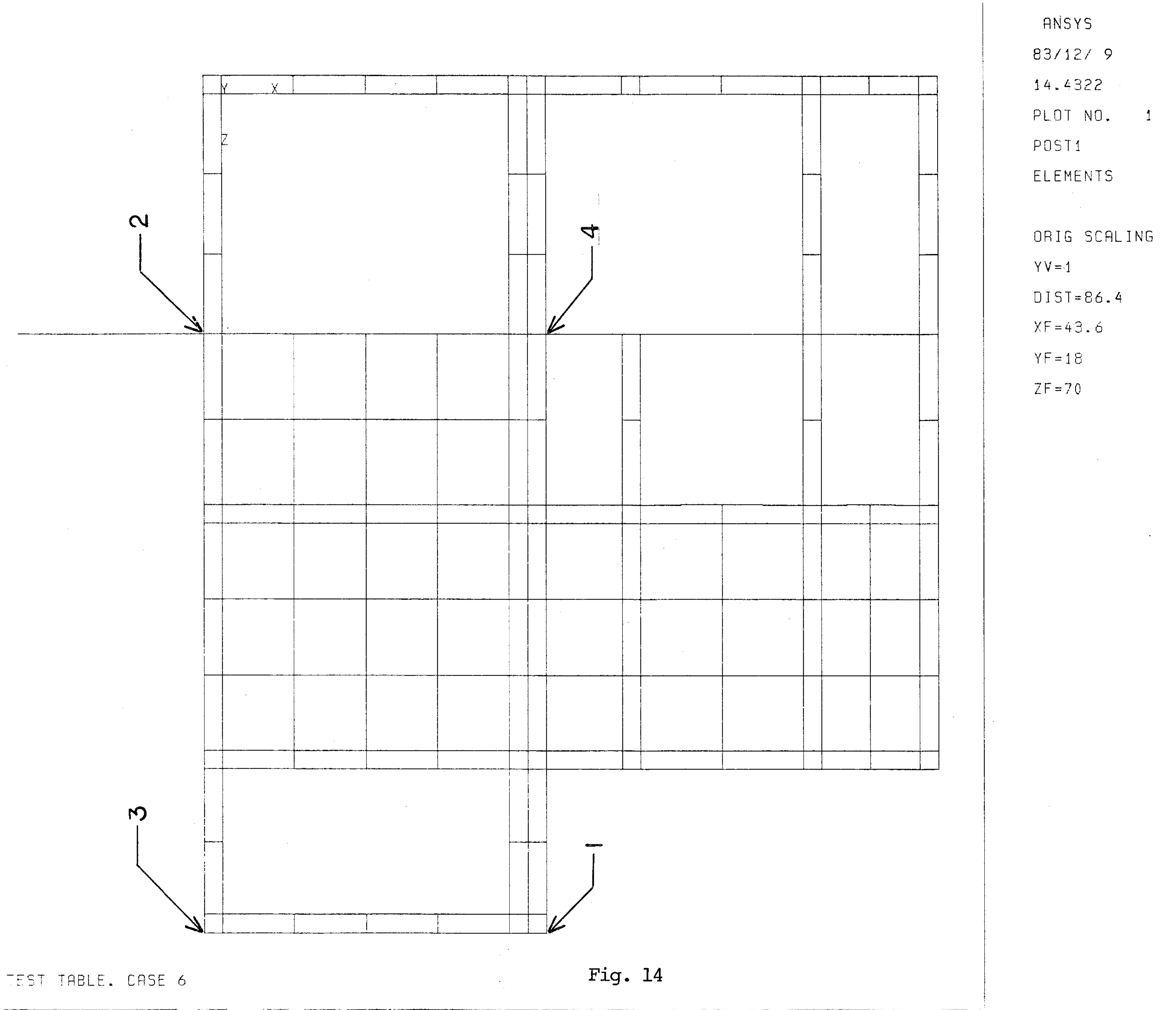

ANSYS
83/12/ 9
14.4322
PLOT NO. 1
POST1
ELEMENTS
ORIG SCALING
YV=1
DIST=86.4
XF=43.6
YF=18
ZF=70
Y
X
Z
2
4
3
1
TEST TABLE. CASE 6

Fig. 14

ANSYS
84/ 1/ 4
10.4528
PLOT NO. 1
POST1
ELEMENTS

ORIG SCALING
YV=1
DIST=98.7
XF=89.7
YF=21
ZF=78.1

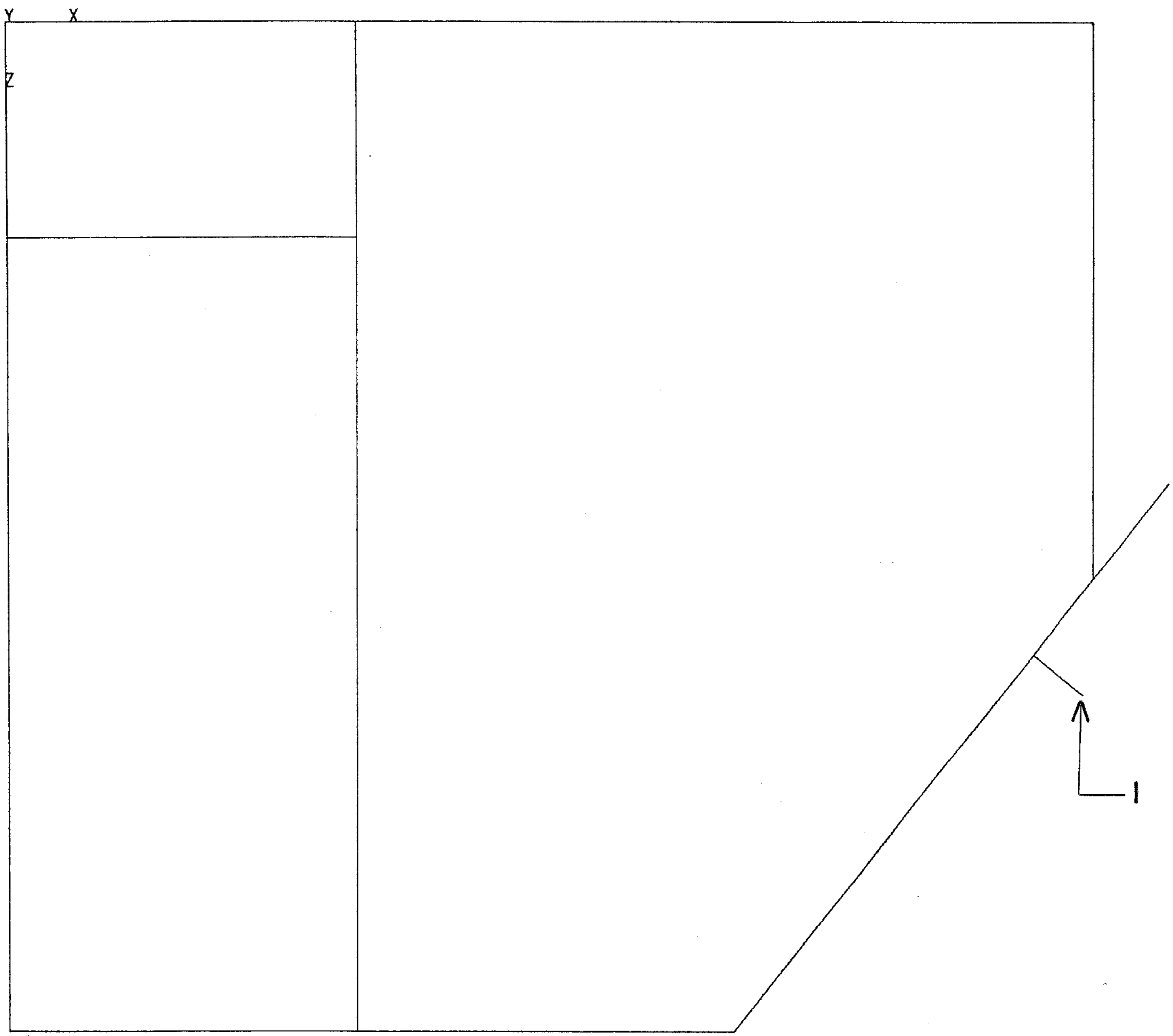


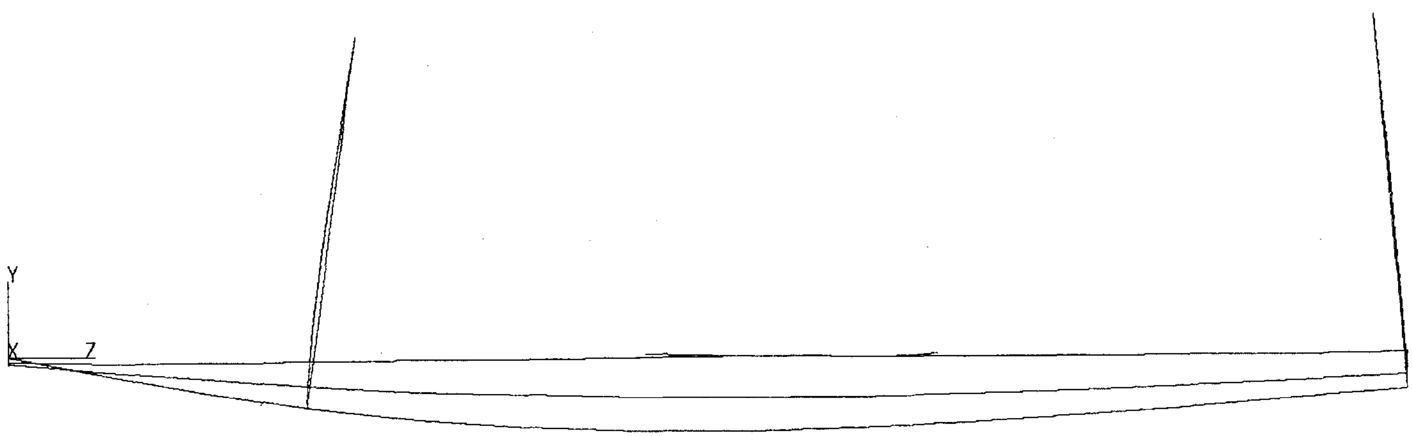
Fig. 15

OUTER FRAME. CASE 1.

1


Y
Z
X
ANSYS
84/ 1/ 3
15.3769
PLOT NO. 3
POST1
STEP=1
ITER=1
DISPLACEMENT
ORIG SCALING
ZV=1
DIST=98.7
XF=89.7
YF=21
ZF=78.1
DMAX=.0915
DSCA=108
OUTER FRAME. CASE 3.

Fig. 16



ANSYS
84/ 1/ 3
15.3689
PLOT NO. 1
POST1
STEP=1
ITER=1
DISPLACEMENT

ORIG SCALING
XV=-1
DIST=85.9
XF=89.7
YF=21
ZF=78.1
DMAX=.0915
DSCA=93.9

Fig. 17

OUTER FRAME. CASE 3.

ANSYS
84/ 1/ 3
15.8561
PLOT NO. 4
POST1
STEP=1
ITER=1
DISPLACEMENT

ORIG SCALING
XV=-1
YV=1
ZV=1
DIST=105
XF=63.4
YF=7
ZF=71.6
DMAX=.483
DSCA=21.7

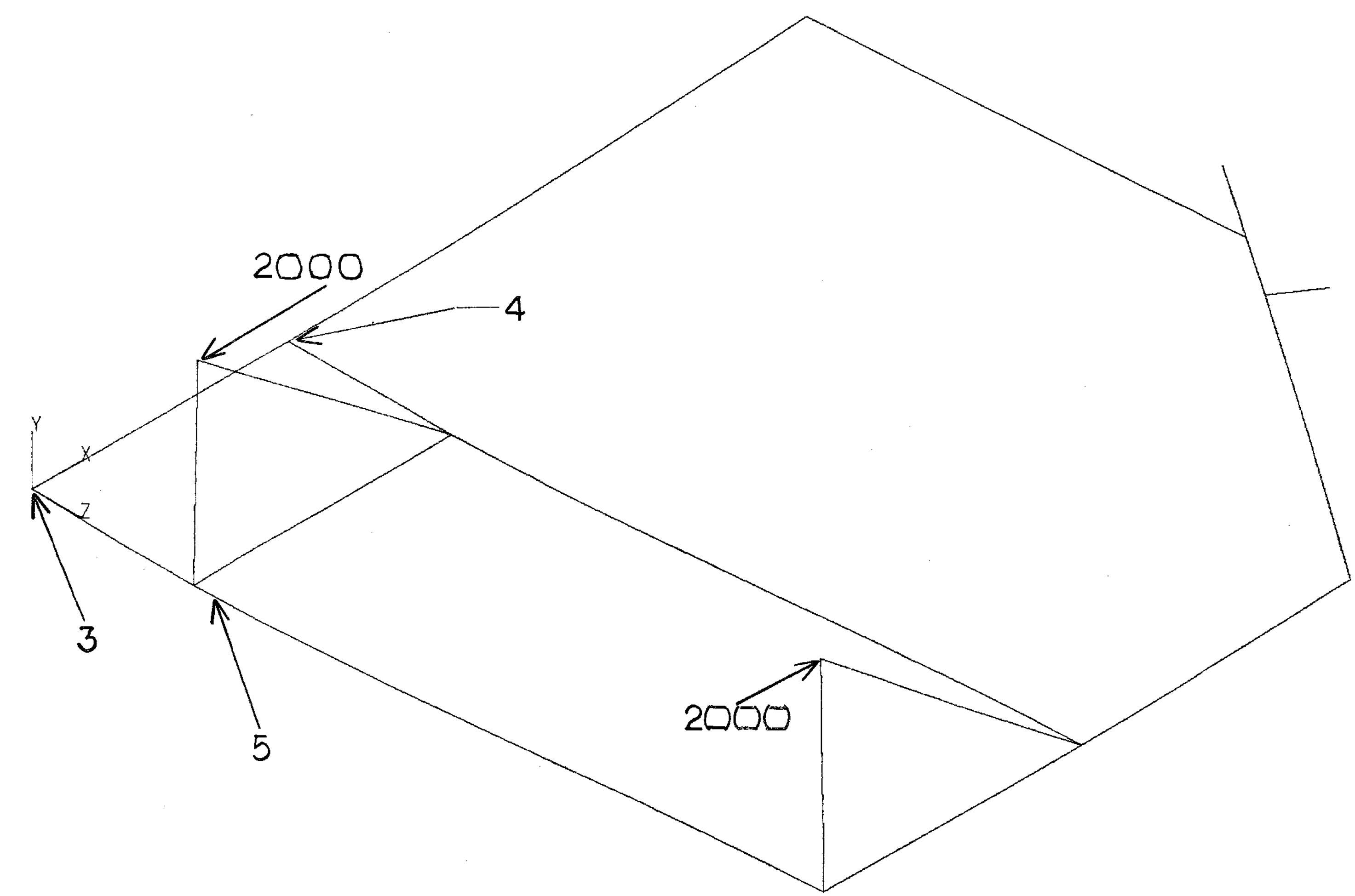


Fig. 18

OUTER FRAME. CASE 4.

1

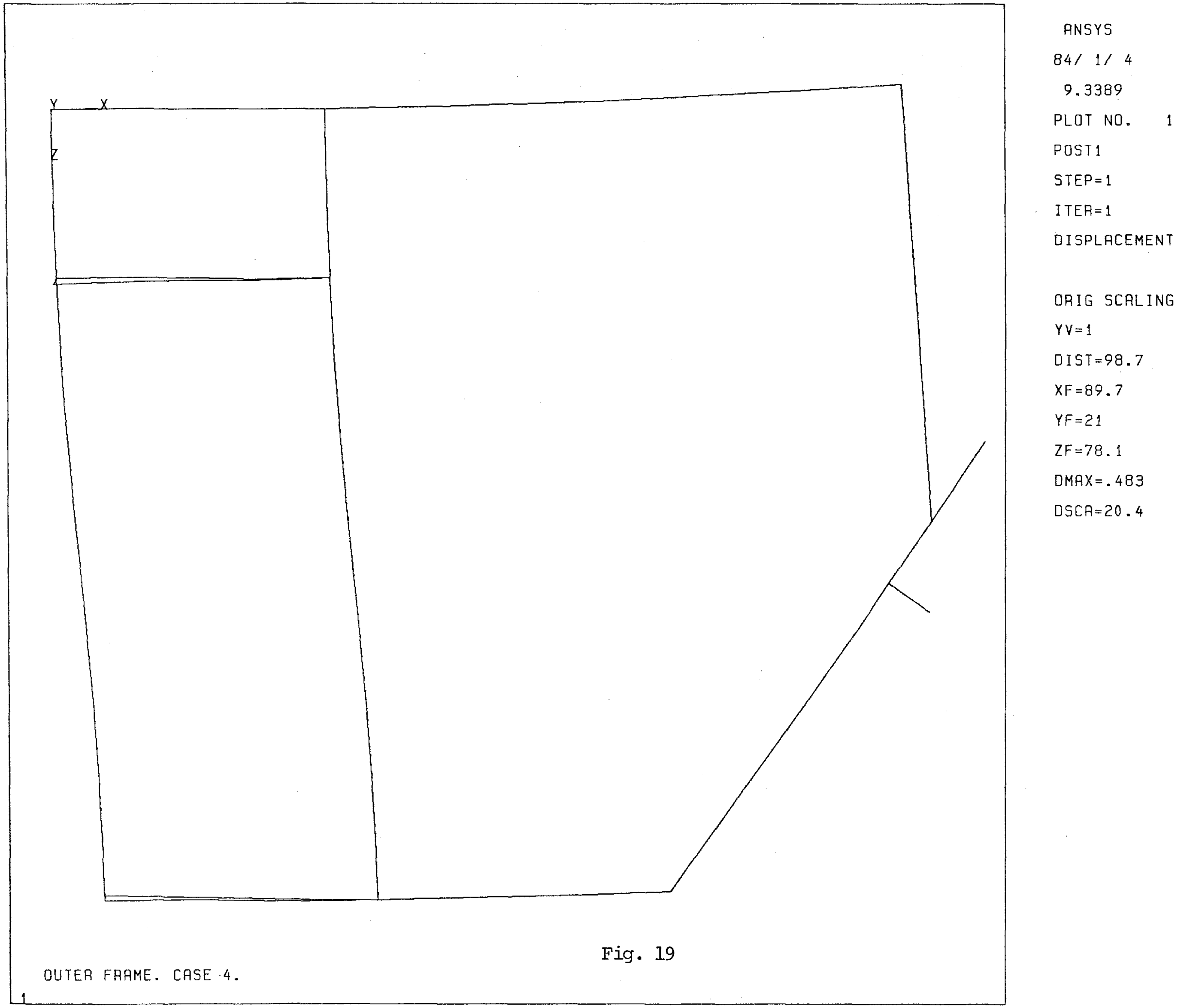

Y
X
Z
ANSYS
84/ 1/ 4
9.3389
PLOT NO. 1
POST1
STEP=1
ITER=1
DISPLACEMENT
ORIG SCALING
YV=1
DIST=98.7
XF=89.7
YF=21
ZF=78.1
DMAX=.483
DSCA=20.4
OUTER FRAME. CASE 4.
1

Fig. 19

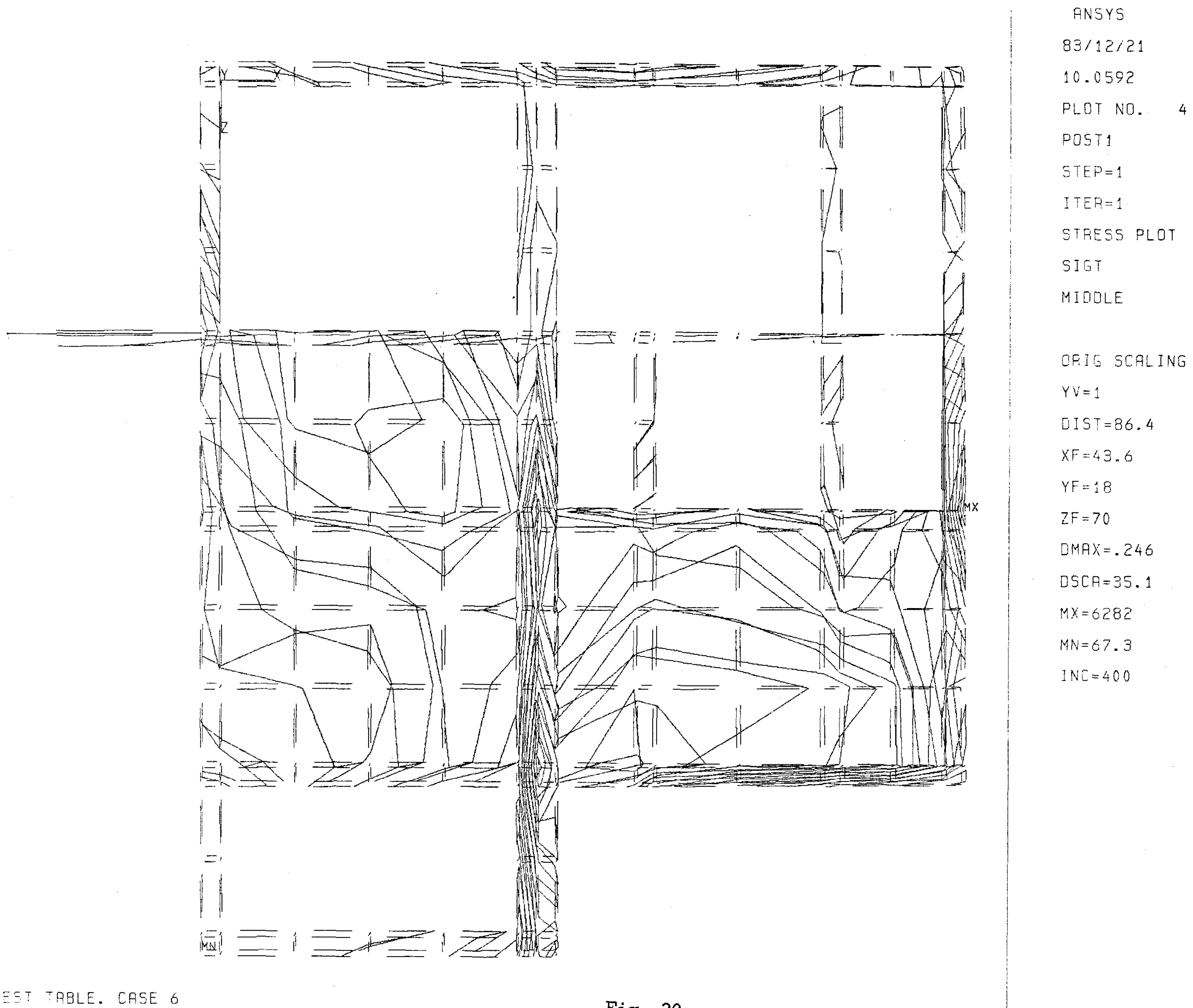
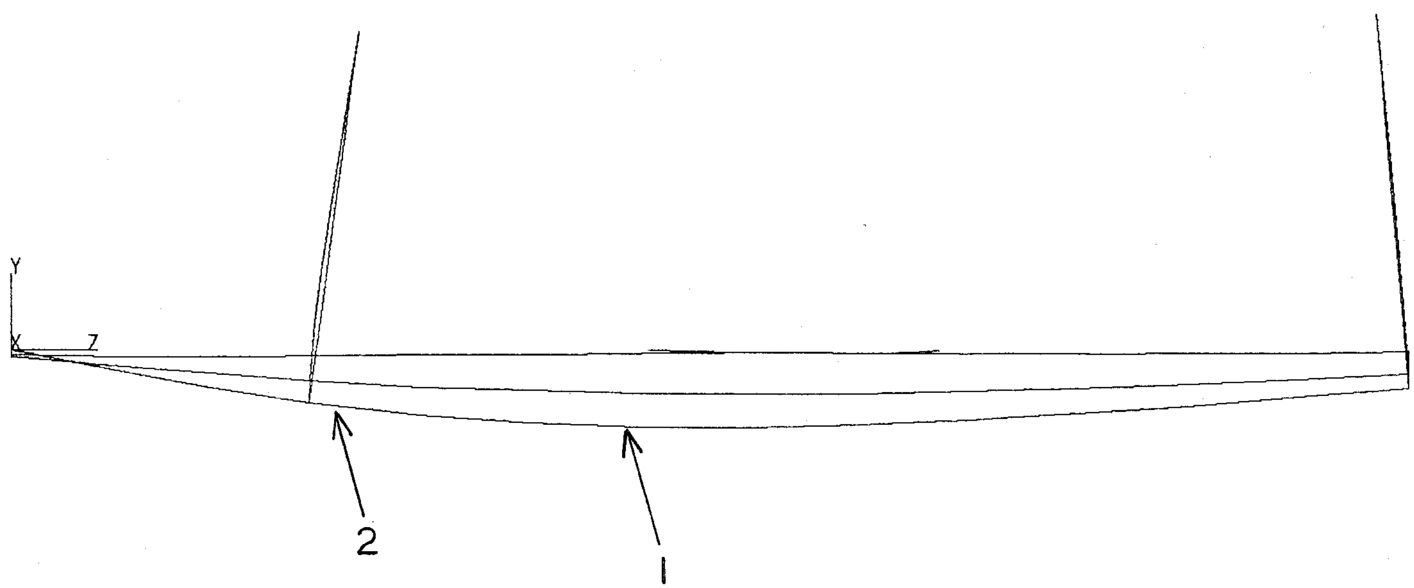

ANSYS
83/12/21
10.0592
PLOT NO. 4
POST1
STEP=1
ITER=1
STRESS PLOT
SIGT
MIDDLE
ORIG SCALING
YV=1
DIST=86.4
XF=43.6
YF=18
ZF=70
DMAX=.246
DSCA=35.1
MX=6282
MN=67.3
INC=400
Y
X
Z
MX
MN
TEST TABLE. CASE 6

Fig. 20



ANSYS
84/ 1/ 3
15.3689
PLOT NO. 1
POST1
STEP=1
ITER=1
DISPLACEMENT

ORIG SCALING
XV=-1
DIST=85.9
XF=89.7
YF=21
ZF=78.1
DMAX=.0915
DSCA=93.9

Fig. 21

OUTER FRAME. CASE 3.